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Using FTIR-ATR and Chemometric Methods to Detect Sucrose Adulteration in Commercial Honey Samples

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ABSTRACT

Fourier transform infrared spectroscopy-attenuated total reflectance (FTIR–ATR) was used to analyze pure and adulterated honey samples. The FTIR spectra was analyzed using principal component analysis (PCA) and partial least squares (PLS) regression analysis to determine if these methods could differentiate between pure, commercial, and sucrose-adulterated honey samples. PCA showed a clear distinction between pure and adulterated honey samples. Commercial honey samples showed clustering around the unadulterated samples. PLS regression analysis correctly identified 81.8% of the standards and samples used in the PCA analysis. The five commercial samples were tested and shown to have a concentration of less than 3% adulterant, which is likely due to differences in sucrose concentration between batches from different locations and bee types. PCA and PLS methods provide a quick and easy analysis of honey samples.

INTRODUCTION

Honey is a popular food item across the world and is widely consumed by humans. The honeybee, *Apis mellifera,* produces honey by consuming nectar from plants such as flowers and trees and converting it into honey using special enzymes that are contained within glands of the bee. The chemical composition of nectar varies between each plant. While the chemical composition may vary between different plants, the main components are sugars such as D-fructose, D-glucose, and sucrose. Other chemical constituents include amino acids, alpha-dicarbonyls, aromatic compounds, flavors, antioxidants, antibacterials, and minerals (Ball, 2007; Marceau, 2009). Location plays a critical role in the chemical composition of honey due to the differences in the plants that are available to the bees (Rios-Corripio, 2011). The enzymes that are used in the production of honey convert sucrose to D-fructose and D-glucose which are stored along with water and the rest of the components such as amino acids or aromatic compounds from

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the nectar. With the demand of honey being so high across the world, there are companies and producers of honey that seek to profit off the sale and distribution of honey. Some producers will add chemicals such as flavor compounds or other sugars to their products to produce a blend of honey that will fare well in the market. This adulteration of honey is harmful to the local producers of honey who do not have as large of a clientele as commercial producers. The adulteration of naturally produced honey could potentially lead to health risks as well if the product is adulterated with impure sugars, flavor compounds, or antioxidants (Cengiz, 2019; Kelly, 2004; Sahlan, 2019). These adulterated products are not tested or deemed safe by the FDA and could lead to harm in consumers if the adulterers added unsafe chemicals to their products. The need to qualify and quantify this information is important for the safety of consumers and for the economic safety of local producers who only produce and sell natural, unadulterated honey.

Many different techniques have been used to detect the adulteration of natural honey including NMR, HPLC, carbon-isotope ratio analysis, gas chromatography, and rheological methods (Cengiz, 2019; Kelly, 2004; Sahlan, 2019). While these methods are useful and effective, they take time and sample preparation. FTIR-ATR methods in the MID-IR allow for a faster and cheaper method of analyzing honey for adulteration due to the ease of operation, speed, cost, and the ability to analyze the method non-destructively. Different vibrational and rotational translations of certain functional groups allow for the detection of different chemicals within the honey mixture (Cengiz, 2019; Kelly, 2004; Sahlan, 2019). The spectral region between 882-944 cm^{-1} can be used to examine the concentration of sucrose in honey. Since the FTIR-ATR spectrum of honey varies between every sample, differences in the sucrose peaks between samples is hard to detect with the naked eye.

The use of chemometrics and multivariate analysis is necessary to distinguish between each category of sample. Principal Component Analysis is a multivariate method that is useful when analyzing large data sets and is used in the forensics and food sciences industries (Kamil, 2015). PCA decreases the dimensionality of a data set by creating new variables, called principal components, through linear combinations of the original data. These new points can be plotted on a 2- or 3-dimensional plot depending on how many principal components are used for the data analysis. Two principal components were used for this analysis. The points are arranged through space according to how correlated or uncorrelated they are to one another.

MATERIALS AND METHODS

Pure honey and adulterated honey were analyzed using a Nicolet IS5 iD7 FTIR equipped with a zinc-selenide ATR and analyzed by Origin-Pro data analysis application. A concentrated sucrose solution was made by dissolving 212 grams of granular sucrose in 100.13 grams of deionized water. This was used as the adulterant and added to pure samples of honey to produce adulterated samples that were between 6% and 22% sucrose solution by weight. Commercial honey products were purchased from the local grocery store and stored in the lab at room temperature.

The spectral region from 882-944 cm^{-1} was analyzed and used for the construction of a Partial-Least Squares regression model and a Principal Component analysis model to determine if

each adulterated sample could be distinguished from the pure samples of honey. Food Lion brand honey was used for the PLS regression model ranging from 0% to 27.22% sucrose by weight. The PCA model was used to distinguish between groups: unadulterated honey, adulterated honey at 7% sucrose, adulterated honey at 14% sucrose, adulterated honey at 21% sucrose, and each commercial honey brand. A total of 48 spectral files were used for the PCA model and a total of 10 samples were used to produce the calibration curve for the PLS model. Origin-Pro PLS and PCA analysis applications were used to predict the level of adulteration of each commercial honey sample as well as the prepared samples.

Five commercial honey brands were analyzed in triplicate to determine if there were any levels of sucrose adulteration in the samples. The five brands were: White Forest Honey, Goya orange blossom honey, Manischewitz clover honey, Golden Farms honey, and Nature's Promise honey. Each sample was purchased from the local Food Lion.

RESULTS

Principal Component Analysis

The PCA plot shows each group of honey separated out in nice thin bands. The four different levels of adulteration are clearly separated. 100% of the variability in the data is accounted for using the first two principal components. A 95% confidence interval is included for each group as well. The score plot for the principal component analysis is shown in Figure 1 below.

Partial Least Squares Regression

A PLS regression model was produced using the Origin-Pro data analysis software and Microsoft Excel. The predicted vs actual adulteration percentage plot shown in Figure 2 below has an equation of $y = 0.9988x + 0.0161$ with an R^2 value of 0.9988. The PLS model was used to predict the concentration of each sample that was used in the PCA model as well as the concentration of each commercial honey sample. The calculated concentration of each sample is listed in Table 1.

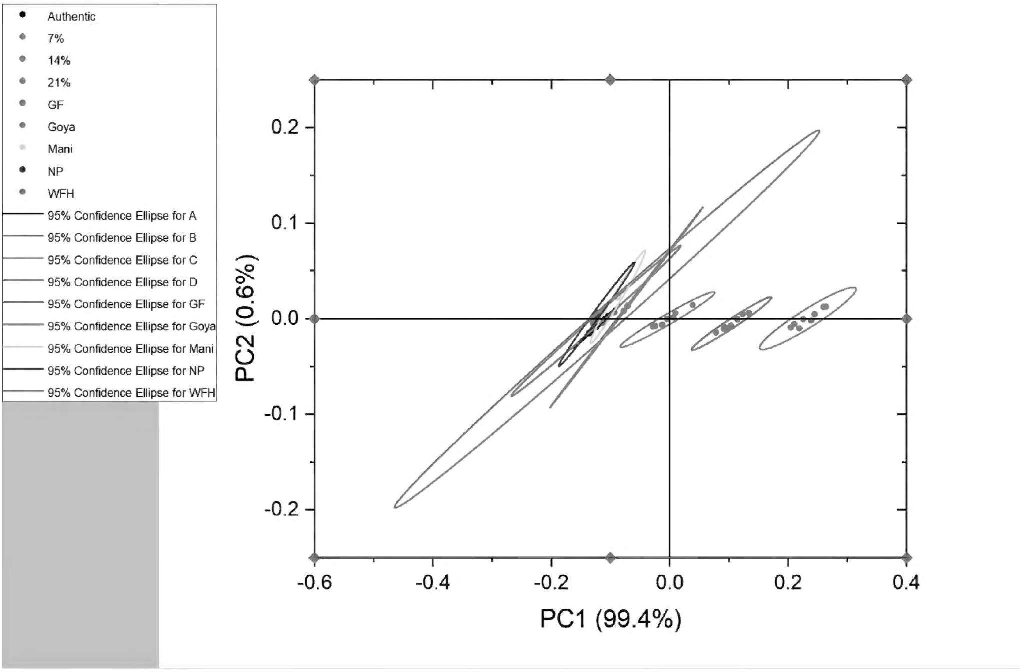

Figure 1: Score plot of each standard honey solution and commercial samples

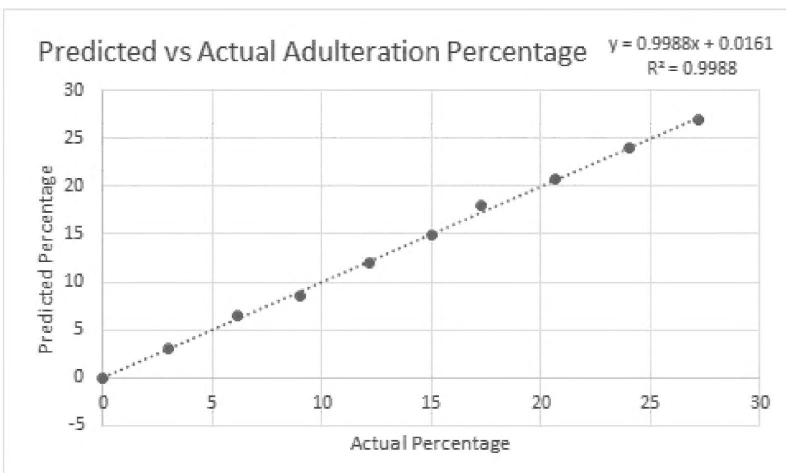

Figure 2: PLS regression model

Table 1: Percentage sucrose adulteration and predicted sucrose adulteration in 33 honey standards

Sample ID	Actual Percent Sucrose Solution	Predicted Percent Sucrose Solution	Percent Difference
A1	0	0.85125	200
A2	0	1.21415	200
A3	0	1.4338	200
A4	0	2.78683	200
A5	0	2.21548	200
A6	0	2.84408	200
A7	0	2.69805	200
A8	0	2.4948	200
A9	0	1.90486	200
B1	6.9	7.43752	7.498089
B2	6.8	7.19152	5.596533
B3	6.5	7.55044	14.95241
B4	7.1	7.94052	11.17674
B5	7.1	8.02862	12.27633
B6	7.2	6.72039	6.890755
B7	6.7	6.78267	1.226315
B8	6.9	7.35974	6.448084
C1	14	14.39514	2.783152
C2	13.8	13.47909	2.352791
C3	14.2	14.10036	0.704161
C4	14	15.03933	7.158085
C5	13.9	14.90923	7.006296
C6	14	14.92098	6.36894
C7	13.8	14.64461	5.938629
C8	14.2	14.87875	4.668357
D1	21.7	22.08961	1.779463
D2	20.9	21.48951	2.781396
D3	21.7	22.53584	3.779017
D4	20.7	20.94383	1.171026
D5	20.8	20.84283	0.205702
D6	20.9	20.29573	2.933654
D7	21.2	20.40079	3.842283
D8	21.1	20.72325	1.801629

DISCUSSION

Principal Component Analysis

The results of the principal component analysis show that as more concentrated sucrose solution is added to the honey, the further the points lie from the original non adulterated honey points. The black points in Figure 1 show the honey samples that contain no adulterant. These points are hard to see because of the overlap with the commercial products, but they cluster approximately -0.1 units to the left of the origin. The adulterated samples move to the right of the origin as the total solution increases the content of concentrated sucrose solution. The points that lie furthest to the right are the honey samples that are approximately 21% sucrose solution. The commercial samples cluster around the pure honey samples which indicate that there is no adulteration with sucrose solution or sucrose syrups. Since the data that was acquired had very little differentiation between each sample, almost 100% of the variability between each sample is described with the first two principal components. This removed the necessity for data pre-treatment to be done before analyzing the data.

Partial Least Squares Regression

Ten data points were used for the construction of the PLS regression model, starting with pure honey and gradually increasing the percentage of sucrose solution until a maximum of 27.22% was reached. The PLS model was used to predict the level of sucrose adulteration in each of the samples used in the PCA model as well as the commercial samples. Samples with predicted values that differ from the actual values by greater than 8% are considered misclassified. Only three samples were misclassified by using this method. The three misclassified samples were in the 7% adulterated category. The rest of the samples were correctly classified into their categories using the PLS model. Using the formula for percent difference shown in Equation 1, the percent difference for each authentic sample is 200%. Any calculated concentration over 2.5% sucrose solution is treated as a misclassification. Three standards were calculated to have a concentration of greater than 2.5%. Using the PLS regression model, 81.8% of the total standards were correctly classified. This is similar that was has been observed for other countries where water and vinegar additions were done. (Mail, 2019; Riswahyuli, 2020)

The commercial samples were analyzed in triplicate and an average concentration of added sucrose solution was calculated using the regression model. The results of these are shown in Table 2. Based on the PLS model and the PCA model, the commercial samples all had predicted concentrations of sucrose solution below 3% while also clustering around the unadulterated points. The highest average concentration of the commercial products was White Forest Organic honey at 2.8%, while the lowest average concentration was Manischewitz clover honey at -2.0%. Based on the PLS model and PCA model, it does not appear that any of the commercial products were adulterated with sucrose. Differences in sucrose content between different brands of honey are due to different types of plants in the region in which the bees collected nectar. Different breeds of honeybee also produce different levels of sucrose in their honey based on the types and levels of enzymes present in each hive of bees. (Marceau, 2009)

Equation 1: Percent difference equation

$$\frac{|y-x|}{\frac{y+x}{2}}$$

Where y is the calculated value and x is the true value

Table 2: Predicted and average predicted concentrations of commercial products

Sample ID	Predicted Concentration	Average Predicted Concentration
GF-1	0.35358	0.658377
GF-2	0.98256	
GF-3	0.63899	
Goya-1	0.51104	0.746893
Goya-2	1.33861	
Goya-3	0.39103	
Mani-1	-1.92198	-2.02729
Mani-2	-1.85725	
Mani-3	-2.30265	
NP-1	-0.7989	-0.47912
NP-2	-0.1187	
NP-3	-0.51977	
WFH-1	2.20786	2.802403
WFH-2	2.43406	
WFH-3	3.76529	

GF = Golden Farms, Goya = Goya, Mani = Manischewitz, NP = Natures Promise, WFH = White Forest Honey

CONCLUSION

FTIR-ATR was used to analyze pure and adulterated honey samples. We were able to differentiate between pure, commercial and sucrose adulterated honey samples by FTIR spectra analyzed by principal component analysis (PCA) and partial least squares (PLS) regression analysis. PCA showed a clear distinction between pure and adulterated honey samples. Commercial honey samples showed clustering around the unadulterated samples. PLS regression analysis correctly identified 81.8% of the standards and samples used in the PCA analysis. Five commercial samples were tested and shown to have a concentration of less than 3% of adulterant, which is likely due to differences in sucrose concentration between batches from different locations and bee types.

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Wetlands in Our Backyard: A Review of Wetland Types in Virginia State Parks

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ABSTRACT

Wetlands constitute a significant component of Virginia's natural resources and heritage. Though historically they have been discounted—and often denigrated—the exceptional value of wetlands is currently growing in recognition and appreciation. In addition to the value provided by extracted resources and ecological regulation, wetlands also offer people the opportunity to enrich themselves through cultural, educational, and recreational pursuits. The state parks of Virginia provide access to a variety of ecosystems, including a wide array of wetland types. In this review, we document the diversity of wetlands in Virginia State Parks through a typology that groups wetland systems into the three principal classes that most people are accustomed to considering: swamps, marshes, and bogs. It is our hope that this review proves accessible and motivating to individuals exploring Virginia's great natural diversity.

INTRODUCTION

The purpose of this review is to provide a typology of wetlands that can be found in Virginia State Parks (VSP). Wetlands in general constitute an ecosystem type whose perceived value has shifted in recent history, leading to increased attention to the task of defining and classifying wetlands. While wetlands on public lands are protected from extractive uses, they nonetheless provide additional ecosystem services such as flood mitigation and carbon sequestration, and they offer individuals a significant range of direct values stemming from their use in cultural, recreational, and educational pursuits. This review is not a rigorous report of the exact size, type, and location of a set of wetlands. Rather, it constitutes a defined list of the kinds

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of wetlands that can be identified, explored, and appreciated within the Virginia State Park system—public lands that constitute our collective backyard.

WETLANDS DEFINITION

Wetlands are defined by the Army Corps of Engineers as "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas" (Environmental Laboratory, 1987, p. 9). These complex ecosystems have been redefined again and again throughout history, with debate over their definition most notably spiking since the enactment of the Clean Water Act in 1972. The period of the 1970s to the early 2000s encompasses a pivotal era of wetland litigation and environmental policy that redefined the way we view and protect our nation's wetlands (Lewis, 2001). Since this era, the field of wetland research has increased substantially, contributing to a better understanding of what a wetland is from a biological, chemical, and ecological standpoint. Alongside this research have come efforts to educate the public on the value and ecological significance of wetlands. Scientific research and educational campaigns together have shifted the public perspective of wetlands from one that historically encouraged the conquering and development of wetlands to one that strives instead to preserve and conserve them (Keddy, 2010). Such a new and ecocentric view acknowledges and values the significance and importance of these diverse ecosystems in their totality.

The Value of Wetlands

Assigning an economic value to any ecosystem is difficult. From a utilitarian perspective, an area designated as a wetland is only as valuable as the resources that can be harvested from it: timber, peat, furs and other animal products, etc. In addition to these provisioning services, wetlands provide value in the form of regulating, cultural, and supporting ecosystem services (Mitsch & Gosselink, 2015). For example, wetlands serve critical functions such as flood mitigation, storm protection, and nutrient cycling. Additionally, wetlands offer innate biological value as rich hubs of biodiversity housing unique obligate species that cannot be found anywhere else in the world. These lands also hold historical, educational, and cultural value tied to religion, traditional medicine, recreational activities, science, and many other services (Millennium Ecosystem Assessment, 2005). In short, wetlands are an invaluable resource for the human and natural societies that surround them. To recognize and appreciate wetlands as a resource, they must be identified and classified.

Classification

The shift in public and federal outlook on wetland systems in the 1970s gave rise to the concept of wetland classification, something that had not yet been undertaken in an organized manner. With the rise of new policies and the need for proper enforcement of these policies came the necessity of an inventory of wetland ecosystems. This need led to the establishment of the National Wetlands Inventory (NWI) in 1974. The U.S. government acknowledged the economic, social, and ecological benefits that we reap from wetland systems and tasked the United States Fish and Wildlife Service (USFWS) to quantify, categorize, and map the distribution of wetlands

present in the nation. In 1979, a comprehensive classification system titled *Classification of Wetlands and Deepwater Habitats of the United States* was published by Cowardin and colleagues; this system forms the basis for the official USFWS and overall federal classification system for wetlands today.

Wetlands are primarily identified and distinguished by their hydrology, edaphology, and vegetation (Mitsch & Gosselink, 2015). Additional defining characteristics include general location and water salinity. The NWI places wetlands into categories based upon these characteristics with the broadest classification being *system type*. The five system types are marine, riverine, estuarine, lacustrine, and palustrine. These system types can further be divided into *subsystems* and *classes*, each of which is determined primarily by the previously mentioned wetland characteristics (Cowardin et al., 1979).

While broad data exist on the distribution of wetland types based on these overarching classifications, there are many more types of wetland to be encountered. Such variety is typically recognized by names including swamps, marshes, cypress domes, fens, bogs, moors, peatland, Carolina bays, vernal pools, kettle ponds, sloughs, mires, ciénegas, pocosins, mangrove swamps, and many others. These wetland types are associated with specific regions of the United States and the wider world, and come with their own known set of defining characteristics. A listing of the wetlands present in a specific geographic area or areas is therefore difficult not only because of the challenge in defining precisely what a wetland is, but also because of the range of methods used to categorize a given wetland. In the following section we describe our process for identifying and categorizing the wetlands present in Virginia State Parks.

DATA COLLECTION

Virginia is home to 41 state parks spread through all regions of the Commonwealth. While Virginia does contain a variety of other public lands at the federal, state, and local levels, we chose to focus on state parks due to their large diversity, wide distribution, and easy accessibility. With such a vast and widely distributed total area, it was important to develop a systematic means of locating and categorizing wetlands in VSP.

Identifying Wetlands in Virginia State Parks

To determine what types of wetlands are located in VSP, we first consulted online resources, particularly the NWI (USFWS, 2021) and its online Wetland Mapper tool. We found that the information provided by this website gave a decent overview of what wetland ecosystems may be present, but it was not sufficient to meet our goals for several reasons. First, the mapping was at a relatively large resolution, such that small wetland areas could be missed entirely. Second, and related to the first reason, the attribution of ecosystem types was at a large scale, which resulted in broad swaths of land receiving the same designation, with little fine-scaled distinction within regions. And third, the NWI uses the system for classifying habitats published by the Federal Geographic Data Committee (FGDC, 2013), which divides habitats based on the principal hydrology of the area in which they are located. According to this scheme, there are five primary divisions of habitat: marine, estuarine, riverine, lacustrine, and palustrine. Thus, marshes may be categorized in any of the four non-marine systems of primary habitat type. And away from the

coasts of rivers, lakes, and estuaries, all types of wetlands would be considered palustrine (a word that, confusingly, comes from the Latin word meaning *marsh*). We therefore decided to divide our typology into the three broad categories of wetlands that are familiar to most people—swamps, marshes, and bogs—which is in line with the thinking of the *Army Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory, 1987). For subdivisions within these three principal types of wetland, however, we employ subdivisions borrowed from the system of Cowardin et al. (1979). Accordingly, we group all marsh types and subtypes together, rather than grouping wetlands based on the principal hydrology of the geographic area in which they are situated.

Review Methods

To gather more nuanced data about the wetlands present in VSP, we communicated with at least one employee associated with each park office. Because of travel and recreation restrictions in place due to the COVID-19 pandemic during the spring and early summer of 2020, we were unable to visit parks in person. We therefore first attempted contact by emailing each park using the address provided on its individual website (ParkName@dcr.virginia.gov). We followed up with phone calls to the park's main office as needed. Sometimes we were able to acquire the necessary information from the first person we contacted, but often we were directed to an individual with more expertise in wetlands. The data detailed below were gathered from park superintendents, chief rangers, volunteer coordinators, interpreter-naturalists, and education support specialists, among others.

For a few parks, we also gathered information from resource specialists, who cover districts containing several VSP. For 13 parks, the Virginia Department of Conservation and Recreation (VA DCR) has issued a *Natural Heritage Technical Report*. Nine of these reports include wetlands as habitats that have been analyzed for a "desired future condition." We used these analyses to confirm or expand upon our accounting of wetlands present in these parks.

We should note that several VSP were not included in our data, for varying reasons: Seven Bends and Clinch River State Park are still under development and do not have a staffed office at this writing; Southwest Virginia Museum Historical State Park does not have appreciable land holdings; and Machicomoco State Park only opened in the spring of 2021. Further, employees at Natural Tunnel, Wilderness Road, Smith Mountain Lake, and Natural Bridge State Parks reported that there were no confirmed wetlands within these VSP. Additionally, though we treat Shot Tower Historical and New River Trail State Parks as distinct VSP in this review due to their separate listings by the VA DCR, it should be noted that they are directly connected and are thus generally referred to in aggregate for purposes of park visitation and recreation.

We include only verified (via personal communication or published report) wetlands in this data set. There is nonetheless potential for inaccuracy if the resources we used (particularly interpersonal communication) were incomplete or incorrect. Additionally, when wetlands were described to us, there is the potential that we did not appropriately match these descriptions to a specific wetland type. We ultimately used several resources to match a wetland's description and general location to a specific wetland type.

For ecosystem features and, especially, details about the flora and fauna present in specific wetland types, we heavily consulted the Virginia Department of Conservation and Recreation's *Natural Communities of Virginia Classification of Ecological Groups and Community Types*, Third Approximation (Version 3.3; 2021). It should be noted that this guide follows the same system of organizing communities as the *Classification of Wetlands and Deepwater Habitats of the United States* (FGDC, 2013). That is, wetlands appear in riverine, estuarine, and palustrine systems. (Lacustrine systems are not yet included in the Virginia guide.) An additional online resource is the United States Environmental Protection Agency's *Classification and Types of Wetlands* (2020), which categorizes wetlands as swamps, marshes, bogs, and fens. Unless otherwise noted, the plants listed as typical of a specific wetland are native to Virginia. An ultimate authority for these plants is the *Flora of Virginia* (Weakley, Ludwig, & Townsend, 2012). Unless clearly indicated as being present, we do not represent that a specific plant can be found in a given state park's wetland, only that certain plants are typical of certain wetlands. Rather than repeatedly cite the above sources, we list them here as a convenient reference for the reader.

Our results are likely to be an underrepresentation of wetlands present in VSP. We made no effort to document the precise location of any wetland, instead simply noting the presence of individual types of wetlands. The documented presence of a wetland in a park could therefore be indicative of one or more wetlands of that type, and the wetland or wetlands could be of any size. We readily admit that this approach does not constitute a thorough, comprehensive accounting of VSP wetlands. While there is a certain likelihood of inaccuracy, we believe this report offers a substantial overview of the wetlands that can be visited in VSP, and its greatest failing more likely stems from omission than false reporting.

STUDY RESULTS: THE WETLANDS OF VIRGINIA STATE PARKS

Virginia has a diverse landscape consisting of five distinct regions ranging in geography from the flat, sandy Coastal Plain to the mountainous, forested region of the Blue Ridge. The five physiographic regions referenced in this paper follow the classification presented in *Overview of the Physiography and Vegetation of Virginia* (Version 2.0; 2021) and consist of the Appalachian Plateau, Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain regions. This topographic variation gives rise to a wide array of wetland types. Approximately 72% of Virginia's wetlands are located within the Coastal Plain region (United States Geological Survey [USGS], 1996). Encompassed in the Coastal Plain region are all of Virginia's estuarine systems, which connect to the Chesapeake Bay and eventually the Atlantic Ocean. A majority of Virginia's larger non-tidal wetlands also exist within the Coastal Plain region, due to its low elevation. Despite the fact that a majority of Virginia's wetlands are located in the Coastal Plain, which houses all of the state's estuarine systems, a remarkable 72% of Virginia's wetlands are categorized as palustrine, a wetland type that is dispersed throughout the state. More specifically, swamps—a forested palustrine wetland—make up 60% of Virginia's wetland area and were frequently cited by VSP officials as a common wetland type (USGS, 1996). A summary of the succeeding findings of this review can be found in Table 1, which reports all confirmed wetland types with their corresponding VSP.

State Park	Wetland Type										
	Shrub Swamp	Broad-leaved Deciduous Swamp	Broad-leaved Evergreen Swamp	Needle-leaved Evergreen Swamp	Seepage Swamp	Depression Swamp	Maritime Swamp	Saltwater Marsh	Freshwater Marsh	Herbaceous Bog	None Reported*
Bear Creek Lake						X					
Belle Isle								X			
Breaks Interstate						X				X	
Caledon	X	X				X		X	X		
Chippokes Plantation		X						X			
Claytor Lake						X					
Clinch River											X
Douthat						X					
Fairy Stone		X									
False Cape	X	X	X				X	X	X		
First Landing		X					X	X			
Grayson Highlands										X	
High Bridge Trail						X					
Holliday Lake	X										
Hungry Mother	X	X									
James River						X					
Kiptopeke		X					X	X	X		
Lake Anna		X			X						
Leesylvania									X		
Mason Neck						X		X	X		
Machicomoco											X
Natural Bridge											X
Natural Tunnel											X
New River Trail						X			X	X	
Occoneechee						X					
Pocahontas			X	X						X	
Powhatan				X	X	X					
Sailor's Creek Battlefield Historic	X	X									
Seven Bends											X
Shenandoah River						X					
Shot Tower						X					
Sky Meadows		X				X					
Smith Mountain Lake											X
Southwest Virginia Museum Historical											X
Staunton River						X					
Staunton River Battlefield		X				X					
Twin Lakes	X	X									
Westmoreland	X	X							X		
Widewater						X			X		
Wilderness Road											X
York River		X						X			

TABLE 1: A reference for which wetland types are present in which Virginia State Parks. *None reported denotes that there are no confirmed wetlands or that the state park was under development at the time of data collection, meaning a wetland inventory could not be completed.

Swamps

Readers familiar with the Great Dismal Swamp may not be surprised that swamps are considered the dominant wetland of Virginia. Though the Great Dismal Swamp is not contained within a Virginia State Park, its infamous name and vast 112,000-acre extent are representative of the comparatively abundant swampland wetlands within VSP. The condition and history of the Great Dismal Swamp also parallel that of most of the state's wetlands. The swamp has undergone major hydrologic alteration due to human development. Natural surface flow has been disrupted by the construction of almost 200 miles of roads and ditches. The Great Dismal Swamp National Wildlife Refuge was not established until 1974, prior to which unregulated development, land use transformation, and resource harvesting occurred freely. This hydrologic alteration has had cascading effects on the water chemistry, biology, and overall ecology of the swamp, which has led to the development of several restoration projects (Eggleston et al., 2018).

A variety of swamp subtypes can be differentiated by their dominant vegetation species. For example, the Great Dismal Swamp is a white cedar swamp. Accordingly, the principal characteristic of a swamp that differentiates it from other wetland types is the presence of woody vegetation, such as trees or shrubs. Swamps in Virginia largely fall into the palustrine category, meaning they have woody vegetation and are permanently or intermittently flooded with no more than 6.6 feet (2m) of fresh water. They are generally located in floodplains and transitional areas between lakes or rivers and upland areas (Cowardin, 1979; USGS, 1996). This location speaks to their criticality in flood control and filtration of floodwaters, as floods typically flush sediments and nutrients from the surrounding land into the watershed.

Of VSP that contain wetland areas, true swamplands were identified in approximately 70% of them. If vernal pools—a type of depressional wetland sometimes categorized as swampland—are included in these calculations, then swamps were found in approximately 88% of wetland-supporting state parks. These parks included the following: Bear Creek Lake, Breaks Interstate, Fairy Stone, False Cape, James River, Mason Neck, Chippokes, Claytor Lake, Douthat, Shenandoah River, Shot Tower, Sky Meadows, Staunton River, Staunton River Battlefield, Widewater, York River, High Bridge Trail, Holliday Lake, Hungry Mother, Pocahontas, Powhatan, Sailor's Creek Battlefield, Twin Lakes, Caledon, New River, Occoneechee, Lake Anna, First Landing, and Westmoreland.

Swamp description types reported by state park officials varied in specificity and included seasonally or temporarily flooded palustrine wetlands, forested wetlands of varying tree types, freshwater forested/shrub wetlands, acidic seepage swamps, depression swamps, vernal pools, bottomland forest swamps, non-riverine flatwood swamps, tidal shrub swamps, maritime swamps with interdunal swales, and tidal forested swamps. Despite a wide variety of names for these differing swamp types, their one commonality is woody vegetation.

Swamp Subtype 1: Shrub Swamps

Freshwater forested and shrub swamps were the most common subtype reported by state park officials. A shrub swamp, or scrub-shrub wetland, has vegetation cover consisting of woody shrub vegetation less than 20 feet tall. Although some estuarine tidal forested wetland and shrub systems were reported in Caledon and Westmoreland State Parks, forested and scrub-shrub

wetlands are most commonly located in palustrine systems in Virginia, such as in Sailor's Creek Battlefield Historic and Twin Lakes State Parks. An additional lacustrine scrub-shrub wetland was identified in Holliday Lake State Park. These scrub-shrub wetlands come in two forms: They are either precursor wetlands to forested swamps, or they are fully mature and stable, consisting of stunted shrub and tree species. Dominant physiognomic groups within these wetlands include true shrubs, young trees, and stunted trees or shrubs that have arisen due to poor growing conditions, such as low nutrient availability (Cowardin et al., 1979). In the case of the scrub-shrub swamps identified within VSP, stunted broad-leaved deciduous swamp species, such as alders (*Alnus spp.*), willows (*Salix spp.*), buttonbush (*Cephalanthus occidentalis*), overcup oak (*Quercus lyrata*), sweetgum (*Liquidambar styraciflua*), and bog birch (*Betula pumila*) are likely present.

Swamp Subtype 2: Forested Wetlands

A forested wetland is also characterized by woody vegetation, but the vegetation must be 20 feet or taller for the wetland to be considered forested rather than shrub covered. These systems are found throughout the United States but are more common in riverine and palustrine systems in the eastern United States. Forested wetlands are structured with an herbaceous layer at the base, a middle layer consisting of shrubs and saplings, and a canopy of mature trees. Many of the reported wetlands in Virginia state parks fall under the classification of forested wetlands. These include broad-leaved deciduous wetlands, bottomland swamps, flatwood swamps, broad-leaved evergreen wetlands, and needle-leaved evergreen wetlands. These specific forested wetland types are characterized by the dominant plant species.

Swamp Subtype 2a: Broad-leaved Deciduous Swamps. Broad-leaved deciduous wetlands can be found in estuarine systems, and when they are, typical species include sea-myrtle (*Baccharis halimifolia*) and marsh elder (*Iva frutescens*). More common in Virginia, however, are palustrine systems, such as in Sailor's Creek Battlefield Historic and Twin Lakes State Parks. In broad-leaved deciduous-dominated palustrine wetlands, it is typical to find species such as alders (*Alnus spp.*), willows (*Salix spp.*), buttonbush (*Cephalanthus occidentalis*), red osier dogwood (*Cornus stolonifera*), honeycup (*Zenobia pulverulenta*), spirea (*Spiraea douglasii*), and bog birch (*Betula pumila*). Some species, such as red maple (*Acer rubrum*), can be found in lesser quantities as well.

Bottomland Hardwood Swamps. One specific forested wetland type identified by state park employees was bottomland (hardwood) swamps. Bottomland swamps are temporarily or seasonally flooded broad-leaved deciduous forested wetlands that occur in river terraces and flood plains of the Piedmont and Coastal Plain. Tidal palustrine forested and scrub-shrub swamps, which act as transitional boundaries between marshland and true bottomland swamps, have been observed in False Cape State Park. Riverine and/or lacustrine bottomland swamps were listed in Caledon, Fairy Stone, York River, Staunton River Battlefield, Westmoreland, and Lake Anna State Parks. Additionally, a bald cypress (*Taxodium distichum*) dominated bottomland swamp was noted in Chippokes Plantation State Park, and black willow (*Salix nigra*) dominated hardwood swamps were reported in Hungry Mother State Park. Additional shrub dominated wetlands with species

such as swamp rose (*Rosa palustris*) and elderberry (*Sambucus canadensis*) surround the towering willows at Hungry Mother State Park.

Dominant species depend largely on floodplain or terrace elevation. The most saturated bottomland forest swamps occur in the Coastal Plain and are either dominated by green ash (*Fraxinus pennsylvanica*) or green ash and red maple (*Acer rubrum*). In areas of low elevation in both the Piedmont and Coastal Plain, these swamps are typically inundated through winter into early spring. Such conditions favor a combination of species including green ash, water hickory (*Carya aquatica*), overcup oak (*Quercus lyrata*), laurel oak (*Quercus laurifolia*), bald cypress (*T. distichum*), and water tupelo (*Nyssa aquatica*). An example of a low elevation bottomland swamp such as this can be seen in Kiptopeke State Park where black ash (*Fraxinus nigra*) presents as a common broad-leaved deciduous species. In higher elevation areas, common species include swamp chestnut oak (*Quercus michauxii*), cherrybark oak (*Quercus pagoda*), shagbark hickory (*Carya ovata*), and sweetgum (*Liquidambar styraciflua*). Though located in the Valley and Ridge region of Virginia rather than in the Piedmont or Coastal Plain, forested and scrub-shrub hardwood dominated swamplands with patches of emergent wetland area were reported in Sky Meadows State Park as well. Here, like in Kiptoepeke State Park, black ash is an abundant species.

Flatwood Swamps. Non-riverine flatwood swamps typically refer to any saturated, forested wetland not formed by a river. These areas are primarily associated with water supply from perched water tables and are found in the Coastal Plain and eastern shore of Virginia. It makes sense, then, that these swamp types were identified in the coastal state parks of Caledon and First Landing, both of which possess a flat, low-elevation topography. When undisturbed, the overstory of this swamp type is typically dominated by species such as swamp chestnut oak (*Quercus michauxii*), cherrybark oak (*Quercus pagoda*), willow oak (*Quercus phellos*), laurel oak (*Quercus laurifolia*), water oak (*Quercus nigra*), pin oak (*Quercus palustris*), and white oak (*Quercus alba*). Common features of these swamps include predominantly sandy, silty, or clay loam soils and shallow winding or braided channels connecting the occasional shallow pond.

Swamp Subtype 2b: Broad-leaved Evergreen Swamps. While found in more saline regions and at lower latitudes than Virginia, mangrove forests serve as a well-known type of broad-leaved evergreen wetland, housing species such as red mangrove (*Rhizophora manglel*), black mangrove (*Avicennia germinans*), and white mangrove (*Lagun cularia racemosa*). Broad-leaved evergreen wetlands in southeastern regions of the United States, such as Virginia, typically support species such as red bay (*Persea borbonia*), loblolly bay (*Gordonia lasianthus*), and sweet bay (*Magnolia virginiana*) (Cowardin et al., 1979). Representatives of Pocahontas and False Cape State Parks were able to identify this wetland type within their parks.

Swamp Subtype 2c: Needle-leaved Evergreen Swamps. Needle-leaved evergreen wetlands have differing dominant tree species depending upon soil type. In nutrient-poor wetlands, which is common of this subtype, black spruce (*Picea mariana*) dominates. However, in the organic soils and peatlands of the east coast, Atlantic white cedar *(Chamae cyparis thyoides)* is the central species. White cedar is a common swamp species in southeastern Virginia, which explains why it was historically a dominant species in the Great Dismal Swamp. Also found in the southeastern United States is the pond pine (*Pinus serotina*), which coexists in broad-leaved evergreen and deciduous shrub forests despite being a needle-leaved species. For example, pond pine exists within the forested hardwood swamps at Kiptopeke State Park. Needle-leaved evergreen wetlands were identified in both Pocahontas and Powhatan State Parks, which neighbor one another.

Swamp Subtype 2d: Seepage Swamps. Also referred to as *baygalls* and *bayheads* (depending on the geographic region), seepage swamps are an additional forested wetland type. They are distinct in that they generally remain saturated—rather than temporarily inundated—due to steep toe-slopes. Seepage swamps have a wide range of soil types, which dictate the dominant species. In the low-nutrient, acidic soils of the Coastal Plain, one can expect to see red maple (*Acer rubrum*), blackgum (*Nyssa sylvatica*), tulip-tree (*Liriodendron tulipifera*) and loblolly pine (*Pinus taeda*) as dominant tree species. Here, the substrate is typically sandier and sometimes peaty. However, some coastal seepage swamps have calcium-rich soils because ravine basins cut deep into old deposits of shell and lime-sand. This soil composition creates a unique subset of coastal seepage swamps where dominant tree species include green ash (*Fraxinus pennsylvanica*), red maple, and tulip-trees.

In the Piedmont region of Virginia, seepage swamps occur in areas with steep drop-offs, such as oxbow lakes and old flood plains. Soil chemistry in these areas lies between the calcareous and highly acidic extremes we see in coastal seepage swamps and provides habitat for species such as red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), white ash (*Fraxinus americana*), tulip-tree (*Liriodendron tulipifera*), spicebush (*Lindera benzoin*), skunk cabbage (*Symplocarpus foetidus*), cinnamon fern (*Osmundastrum cinnamomeum*), orange jewelweed (*Impatiens capensis*), and clearweed (*Pilea pumila*). According to data compiled by a regional state park resource specialist, both Powhatan and Lake Anna State Parks contain acidic seepage swamp types. These parks lie within the transitional boundary between the Coastal Plain and Piedmont regions of Virginia. Lake Anna in Lake Anna State Park was created by damming the North Anna River, which may have created some steep, ravine-like cutoffs. Powhatan State Park houses the James River, which has a steep riverbank in many areas. Both of these situations—one topographic and one hydrologic—create conditions for the formation of seepage swamps.

Swamp Subtype 2e: Depression Swamps. Depression swamps vary from herbaceous to forested freshwater wetland types. These wetlands are found within the Coastal Plain region of Virginia in topographic areas of low elevation or in areas with perched water tables. Depression swamps can also be found in the Piedmont region in areas with karst topography that have underlying marl and limestone, though they are less

common here than in the Coastal Plain. They are characterized by pockets of comparatively low elevation, which gives them their name. Soil and water chemistry are generally rather acidic in these wetlands, but seasonality and depth of inundation vary, which in turn affect community composition most significantly in these wetlands.

Common herb species adapted to longer inundation periods are southern waxy sedge (*Carex glaucescens*), cypress-swamp sedge (*Carex joorii*), Walter's sedge (*Carex striata*), long-tubercled spikerush (*Eleocharis tuberculosa*), square-stem spikerush (*Eleocharis quadrangulata*), creeping rush (*Juncus repens*), narrow-leaved seedbox (*Ludwigia linearis*), globe-fruited seedbox (*Ludwigia sphaerocarpa*), tall flat panic grass (*Coleataenia rigidula*), warty panic grass (*Panicum verrucosum),* mermaid-weed (*Proserpinaca palustris* and *Proserpinaca pectinata*), short-bristled horned beaksedge (*Rhynchospora corniculata*), narrow plumegrass (*Saccharum baldwinii*), woolgrass (*Scirpus cyperinus*), and pale mannagrass (*Torreyochloa pallida*). Tree dominated depression swamps typically host red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), swamp tupelo (*Nyssa biflora*), blackgum (*Nyssa sylvatica*), willow oak (*Quercus phellos*), overcup oak (*Quercus lyrata*), and bald cypress (*Taxodium distichum*).

Lacustrine and palustrine depression wetlands were identified in James River State Park, and Coastal Plain depression wetlands were reported in Caledon, Mason Neck, Widewater, and Powhatan State Parks. A hardwood tree dominated upland depression swamp was also located in Staunton River Battlefield State Park. Depression wetlands such as these are important ecosystems to preserve as they provide habitat to three endangered amphibian species: Mabee's salamander (*Ambystoma mabeei*), tiger salamander (*Ambystoma tigrinum*), and the barking tree frog (*Hyla gratiosa*). Furthermore, they are habitat for the endangered chicken turtle (*Deirochelys reticularia*) and rare flora such as Harper's fimbristylis (*Fimbristylis perpusilla*) and pondspice (*Litsea aestivalis*). Depression wetlands are fairly uncommon, so protection of the rare and unique habitat they provide is essential.

Vernal Pools. One specific type of depression wetland is a vernal pool. Vernal pools, also known as ephemeral ponds or pools, are small depressional wetlands with gentle slopes and low porosity bedrock or clay substrate that fill every winter and spring but dry up almost entirely during summer and fall. They are frequently surrounded by forested or shrub-covered habitat. These habitats were noted in Bear Creek Lake, Breaks Interstate, New River, Shot Tower, Occoneechee, Shenandoah River, High Bridge, Claytor Lake, Douthat, James River, Sky Meadows, Staunton River, and Powhatan State Parks. Vernal pools come to life during the wet season as eggs and seeds that have laid dormant during the dry season begin to hatch and sprout. These distinctive ecosystems play a vital role in the life history of many wetland species and act as a seasonal food supply for a plethora of bird species such as egrets, ducks, and hawks (Colburn, 2004).

Wet Weather Springs. Similar to vernal pools, wet weather springs, or just wet springs, are seasonally filled with water. When precipitation occurs, it

percolates down through the soil layers until it hits an impermeable rock or thick clay layer. At this point, the water begins to travel along the impermeable layer until it reaches a permeable area or exit point. At the base of steep soil banks and in areas of low elevation, this water exits the soil or cavern it was flowing through and collects to form a spring. Wet springs are comparable biologically and hydrologically to vernal pools, as they typically occur ephemerally and support similar flora and fauna. These wetland types were reported in New River and Shot Tower State Parks.

Swamp Subtype 2f: Maritime Swamps and Interdunal Swales. Maritime swamps are present in estuarine systems of varying salinity. They are forested or, occasionally, shrub wetlands due to environmental conditions leading to stunted growth. The shrub varieties of this wetland typically have surface water present year-round and are supplemented by perched water tables that fill seasonally. Forested maritime swamps tend to have seasonal inundations and are protected by interdunal swales—small, low flats or depressions surrounding the forested wetlands. Interdunal swales surround mature or maturing maritime swamps and are similar in composition to shrub maritime swamps, but on a smaller spatial scale.

The dominant species in shrub maritime swamps is wax myrtle (*Morella cerifera*), but farther south additional dominant species like inkberry (*Ilex glabra*) and highbush blueberries (*Vaccinium spp.*) can be seen. A common companion to these dominating species is poison ivy (*Toxicodendron radicans*), which intertwines with the shrubs in maritime swamps. In forested maritime wetlands, one can expect to see overstory species such as red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), swamp tupelo (*Nyssa biflora*), blackgum (*Nyssa sylvatica*), black willow (*S. nigra*), sweetbay magnolia (*Magnolia virginiana*), loblolly pine (*Pinus taeda*), Atlantic white-cedar (*Chamaecyparis thyoides*), and occasionally bald cypress (*Taxodium distichum*). Maritimes swamps are known to exist in False Cape, Kiptopeke, and First Landing State Parks but are still considered relatively rare in Virginia. In fact, they are becoming increasingly rarer as they continue to face threats from agricultural runoff, coastal development, and logging, even under today's more comprehensive wetland protection policies.

Marshes

The second most abundant wetland type in Virginia is marsh. Tidal marshes are the most dominant, making up 8% of Virginia's total wetland area (USGS, 1996). Tidal marshes have hydrologic regimes driven by oceanic water movement and are typically herbaceous. They can occur as estuarine with varying levels of salinity or they can occur as freshwater systems. Some of the most important functions of these marshes are their ability to dampen the effects of tropical storms, filter out excess nutrients, and provide habitat and nursery grounds for important fisheries species (Millennium Ecosystem Assessment, 2005).

Marsh Subtype 1: Tidal Saltwater Marshes

Salt marshes are characterized by their low species diversity compared to other wetland types. They line the Chesapeake Bay of Virginia in the Coastal Plain region and are categorized

as either oligohaline, mesohaline, or polyhaline with respective salinities of 0.5-5 ppt, 5-18 ppt, and 18-30 ppt. The most dominant natural grass in Virginia tidal oligohaline marshes is big cordgrass (*Spartina cynosuroides*). In riverine-influenced mesohaline and polyhaline systems, marshes are dominated by big cordgrass, saltmarsh cordgrass (*Spartina alterniflora*), and saltmarsh bulrush (*Bolboschoenus robustus*). Non-riverine systems are characterized more by a combination of saltmarsh cordgrass, saltmeadow cordgrass (*Spartina patens*), and saltgrass (*Distichils spicata*). Marshes of all three salinity gradients are thought to be present at Belle Isle State Park. Additional tidal oligohaline marshes were identified in Caledon State Park, and mesohaline and polyhaline marshes were found in First Landing State Park. Tidal saltwater marshes were also located throughout Chippokes Plantation, York River, Mason Neck, Kiptopeke, and False Cape State Parks, though specific salinity classifications were not available.

Marsh Subtype 2: Tidal Freshwater Marshes

Tidal freshwater marshes have an average salinity of less than 0.5 ppt and occur where saltwater from brackish or saline systems meets larger amounts of freshwater from upstream. These habitats best suit arrow-arum (*Peltandra virginica*), dotted smartweed (*Persicaria punctata*), wild rice (*Zizania aquatica*), pickerelweed (*Pontederia cordata*), rice cutgrass (*Leersia oryzoides*), tearthumbs (*Persicaria arifolia* and *Persicaria sagittata*), and beggar-ticks (*Bidens laevis* and *Bidens trichosperma*), though other species are also present. Tidal and intertidal freshwater marshes were identified in Leesylvania, Kiptopeke, Caledon, New River, Mason Neck, Widewater, and Westmoreland State Parks.

Bogs

Traditional bogs are a type of palustrine emergent wetland layered with organic-rich soil from plant detritus and poorly oxygenated, stagnant waters. Other palustrine emergent wetlands similar to bogs are fens and wet meadows, sharing the same peaty or organic soil bed but differing in water supply source (Finlayson, Milton, & Prentice, 2018; USGS, 1996). While true bogs possess peaty soils that grow increasingly acidic with age, the term can be generalized to encompass a variety of seepage wetlands possessing acidic or organic rich soil. Bogs and fens are both classified as geogenous peatlands; because of this shared classification, fens are sometimes referred to as alkaline bogs or other bog variants (Bridgham at al., 1996; McCormac, 1994; Stewart & Kantrud, 1971). In Virginia, bogs are largely seen in the troughs of the Appalachian Mountains but are also present in some depressions and slopes of the Piedmont and Coastal Plain regions.

Bog Subtype 1: Appalachian Bogs

Appalachian bogs are present primarily in the Appalachian Mountains within the Valley and Ridge region of Virginia. These bogs are created from groundwater seepage in flat or slightly aslant low-lying areas, similarly to seepage swamps. Appalachian bogs, however, are less densely forested when compared to swampland and have sparser woody and shrubby vegetation with higher coverage of graminoid species. Soil composition of Appalachian bogs can range from deep-layered peaty soils to mineral-rich soils. Despite the differences in soil types, vegetation communities in Appalachian bogs are differentiated by elevation.

Common shrub species in most Appalachian bogs include smooth alder (*Alnus serrulata*), great rhododendron (*Rhododendron maximum*), silky willow (*Salix sericea*), and Catawba rhododendron (*Rhododendron catawbiense*). Common herbaceous species include tawny cottongrass (*Eriophorum virginicum*), cinnamon fern (*Osmundastrum cinnamomeum*), Fraser's marsh St. Johns-wort (*Hypericum fraseri*), brownish beaksedge (*Rhynchospora capitellata*), and prickly bog sedge (*Carex atlantica*). Distinct vegetation communities are separated into two groups: low elevation communities, which grow below 3,000 feet, and high elevation communities, which grow above 3,000 feet in elevation. Low elevation bogs can be found from the Cumberland Mountains of Virginia into the Valley and Ridge region. Common flora in these low-lying bogs are bushy bluestem (*Andropogon glomeratus*), tussock sedge (*Carex stricta*), tuberous grass-pink (*Calopogon tuberosus*), yellow fringed orchid (*Platanthera ciliaris*), Nuttall's reed-grass (*Calamagrostis cinnoides*), pitch pine (*Pinus rigida*), and round-leaved sundew (*Drosera rotundifolia*).

High elevation bogs are located in the Blue Ridge and Allegheny Mountains as well as in the tallest ridges of the Valley and Ridge region of Virginia. Common herbaceous species include rough-leaved goldenrod (*Solidago patula*), bog goldenrod (*Solidago uliginosa*), Cuthbert's turtlehead (*Chelone cuthbertii*), star sedge (*Carex echinata*), narrow-leaf bur-reed (*Sparganium emersum*), bog willow-herb (*Epilobium leptophyllum*), narrow-panicled rush (*Juncus brevicaudatus*), three-seeded sedge (*Carex trisperma*), Ruth's sedge (*Carex ruthii*), and thyme-leaf bluets (*Houstonia serpyllifolia*). Shrub varieties found at these elevations often include long-stalked holly (*Ilex collina*), northern wild raisin (*Viburnum cassinoides*), Carolina laurel (*Kalmia carolina*), cranberry (*Vaccinium macrocarpon*), and a stunted variation of the red spruce (*Picea rubens*).

An Appalachian seep bog was reported at Breaks Interstate State Park and additional Appalachian bogs were reported at Grayson Highland State Park. Breaks Interstate is located in the Appalachian Plateau region in the southwestern portion of Virginia. The park encompasses the Cumberland Mountains and has an average elevation of approximately 2,000 feet. For this reason, the Appalachian bogs located in Breaks Interstate State Park would be considered low elevation Appalachian bogs. Grayson Highland State Park is located in the Blue Ridge region of Virginia, sitting adjacent to the two tallest mountain peaks in the state, Mount Rogers and Whitetop Mountain. With elevations reaching over 5,000 feet, it is likely that high elevation plant varieties are present in the Appalachian bogs of Grayson Highland State Park.

Bog Subtype 2: Non-tidal Freshwater Marshes

Though referred to as marshes by some, non-tidal freshwater marshes fall under the same generalized definition of bog commonly used in the southeastern United States. They are emergent or scrub-shrub wetlands that host vegetation communities composed largely of soft-stemmed grasses, sedges, and wetland wildflower species. Nontidal freshwater marshes can occur in lake or river peripheries, prairie potholes, and valley regions. Depending on the area's geology, non-tidal freshwater marshes can be saturated with either surface or groundwater and generally remain inundated throughout the entirety of fall and spring, considered the growing season in the southeastern United States. Prairie potholes, wet meadows, playa lakes, and some vernal pools

can be categorized as non-tidal freshwater marshes depending on their environmental characteristics (Colburn, 2004). In addition to their hydrologic regime, another defining characteristic of a non-tidal freshwater marsh is a soil bed composition of mineral- and organic-rich sands, silts, and clays, which is why they are ultimately considered a type of bog.

Because of their rich soil, non-tidal marshes are micro-hotspots for biodiversity, supporting a plethora of flora and fauna. A few common plant species include marsh fern (*Thelypteris palustris*), cattail (*Typha spp.*) and pickerelweed (*Pontederia cordata*). Additionally, these marshes serve as prime habitat for water birds such as the great blue heron (*Ardea herodias*) as well as other strongly water-associated birds such as the red-winged blackbird (*Agelaius phoeniceus*). Small mammalian predators like the otter (*Lontra canadensis*) and mink (*Mustela vison*), as well as the water-dependent muskrat (*Ondatra zibethicus*), are also supported by these diverse habitats. These systems, similarly to coastal tidal marshes, also help to trap excess nutrients and sediments from surface runoff while mitigating potential damage from flood waters. New River State Park, located in the Valley and Ridge region, reported non-tidal lacustrine marshes. Pocahontas State Park, which straddles the boundary between the Piedmont and Coastal Plain regions, also contains some non-tidal freshwater marshland. Lastly, Breaks Interstate State Park has a non-tidal freshwater marsh, which park officials classified as a wet meadow.

CONCLUSION

Virginia is dominated by beautiful forested and shrub palustrine swamp wetlands with accents of herbaceous marshland and bogs. Within this mixture of wetland subtypes exist rare ecosystems such as maritime and depression swamps. Virginia's diverse landscape allows for a variety of wetland ecosystem subtypes to persist within the state. Despite palustrine systems dominating the state, we still see in some capacity all five overarching wetland types and a plethora of specific subtypes such as seepage swamps and riverine tidal freshwater marshes. Table 2 provides a full view of all wetlands types found in VSP, incorporating both the system used in the *Classification of Wetlands and Deepwater Habitats of the United States* (FGDC, 2013) as well as the standard divisions of swamp, marsh, and bog. As a more accessible guide to wetlands in VSP, Table 3 provides a condensed overview using only the common names of generalized wetlands types, many of which have been subsumed from the finer gradations within Table 2. Even with such diversity, all these systems have one commonality: they provide so much for the people and organisms that inhabit and surround them.

Virginia's wetlands provide habitat to endemic, rare, and threatened species, making them critically important from a biological standpoint. Furthermore, no matter the type, these wetlands provide critical ecosystem services to Virginians. They protect our coastal communities, boost our economy through fisheries and tourism, filter our water, enrich our culture and educational systems, help fight global climate change through carbon sequestration, provide us with recreational outlets, and so much more—the list goes on and on. From the Great Dismal Swamp to the smallest seasonal vernal pool, these ecosystems hold inestimable value and are undoubtedly part of what makes Virginia, Virginia.

TABLE 2: A complete typology of wetlands present in Virginia State Parks, including the system name derived from the Cowardin classification system and determined by general location and hydrology (column 1; Cowardin et al., 1979), as well a novel subsystem classification developed using common names of wetlands accrued through research of the literature for this review (column 2). Type, subtype, and subset classifications are derived from categorization of wetlands by Cowardin and the Virginia Department of Conservation and Recreation (Cowardin et al., 1979; Fleming & Patterson, 2017).

System	Subsystem	Type	Subtype	Subset	Number of State Parks
Palustrine	Swamp	Shrub	------------------------------	----------------------------	4
		Forested	Broad-leaved deciduous	Bottomland Hardwood	4
				Flatwood	2
				----------------------------	2
			Broad-leaved evergreen	----------------------------	2
			Needle-leaved evergreen	----------------------------	2
			Seepage	----------------------------	1
			Depression	Vernal Pool	13
				Wet Weather Spring	2
				Other	6
	Bog	Herbaceous	------------------------------	Appalachian	2
			Non-tidal	Freshwater Marsh	3
Lacustrine	Swamp	Forested	Depression	Other	1
			Broad-leaved deciduous	Bottomland Hardwood	3
				----------------------------	1
			Seepage	----------------------------	1
		Shrub	------------------------------	----------------------------	2
Riverine	Swamp	Forested	Broad-leaved deciduous	Bottomland Hardwood	3
		Shrub	------------------------------	----------------------------	1
	Marsh	Herbaceous	Freshwater	Tidal/Intertidal	8
Estuarine	Swamp	Shrub	------------------------------	Tidal	1
			Maritime and Interdunal Swales	----------------------------	3
		Forested	Broad-leaved deciduous	Tidal	1
			Maritime and Interdunal Swales	----------------------------	3
	Marsh	Herbaceous	Oligohaline	Tidal	2
			Mesohaline	Tidal	2
			Polyhaline	Tidal	2
			Salinity not specified	Tidal	5

TABLE 3: A quick reference guide to wetlands present in Virginia State Parks using generalized names.

Wetland Type	Number of State Parks
Shrub Swamp	7
Broad-leaved Deciduous Swamp	14
Broad-leaved Evergreen Swamp	2
Needle-leaved Evergreen Swamp	2
Seepage Swamp	2
Depression Swamp	17
Maritime Swamp	3
Saltwater Marsh	8
Freshwater Marsh	8
Herbaceous Bog	3

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